

SOME CONTRIBUTIONS OF AN EXPERIMENTAL ANALYSIS OF BEHAVIOR TO PSYCHOLOGY AS A WHOLE¹

B. F. SKINNER

Harvard University

FREQUENCY OF RESPONSE AND PROBABILITY OF ACTION

ALL psychologists study behavior—even those who believe this to be merely a step toward a subject matter of another sort. All psychologists therefore face certain important common problems. The “pure” experimental study of behavior in either the field or the laboratory is by its very nature concerned with problems of this sort. Any progress it may make toward solutions should be of interest to everyone who deals with behavior for any reason whatsoever.

As an example, let us consider a concept which, in the most general terms, may be called “probability of action.” Behavior which has already occurred and may never be repeated is of limited interest. Psychologists are usually especially concerned with the future of the organisms they study. They want to predict what an individual will do or at least to specify some of the features which his behavior will exhibit under certain circumstances. They also frequently want to control behavior or to impress certain features upon it. But what sort of subject matter is *future* behavior? How is it represented in the organism under observation?

Generally it is argued or implied that when we predict or arrange a future course of action, we are dealing with some contemporary state of the organism which represents the specified action before it has taken place. Thus, we speak of tendencies or readiness to behave as if they corresponded to something in the organism at the moment. We give this “something” many names—from the preparatory set of experimental psychology to the Freudian wish. Habits and instincts, dispositions and predispositions, attitudes, opinions, even personality itself, are all attempts to represent in the present organism something of its future behavior.

Probability of action has been given the physical status of a *thing*. It has been, so to speak, *embodied* in the organism—in the neurological or psychic states or events with which habits, wishes, attitudes, and so on may be identified. This solution has forced us to assign extraneous properties to behavior which are not supported by the data and which have been quite misleading.

The physical referent of a probability must be among our data or the problem would not have been so persistent. The mistake we make is in looking for it as a property of a single event, occupying only one point in time. As the mathematicians have noted, perhaps not unanimously, a probability is a way of representing a frequency of occurrence. In the program of research to be summarized and exemplified here, probability of action has been attacked experimentally by studying the repeated appearance of an act during an appreciable interval of time.

Frequency of response is emphasized by most of the concepts which have foreshadowed an explicit recognition of probability as a datum. An organism possesses a “habit” to the extent that a certain form of behavior is observed with a special frequency—attributable to events in the history of the individual. It possesses an “instinct” to the extent that a certain form of behavior is observed with a special frequency—in this case because of membership in a given species. An “attitude” expresses a special frequency of a number of forms of behavior. These frequencies are the observable facts and may be studied as such rather than as evidence for the embodiment of probability in neural or psychic states.

Dozens of less technical terms serving the same purpose point to an all-abiding practical and theoretical interest in frequency of response as a datum. We say that someone is a tennis fan if he *frequently* plays tennis under appropriate circumstances. He is “enthusiastic” about skating, if he *frequently*

¹ Adapted from a lecture at the Thirteenth International Congress of Psychology in Stockholm, Sweden, July 1951.

goes skating. He is "greatly interested" in music if he plays, listens to, and talks about music *frequently*. The "inveterate" gambler gambles *frequently*. The "highly sexed" *frequently* engage in sexual behavior. The linguistic effect of terms of this sort—as of the more technical terms—is to move from an observation of frequency to an inferred momentary condition. But this should not be allowed to influence the direction of our research. The basic facts can be discovered only by examining behavior during appreciable intervals of time.

In designing a laboratory situation in which frequency of response may be easily examined certain considerations must be observed. We must choose a sample of behavior which may be so easily identified that repeated instances may be reliably counted. If our experiment is to be automatic—and there are many advantages in making it so—the chosen response must operate an apparatus. The response should not require much time, and it should leave the organism ready to respond again. These conditions are rather arbitrary, and our results must be qualified accordingly, but they are easily met. Sometimes such a response is found ready-made—as in studying so-called instinctive behavior. At other times it must be, so to speak, constructed. In the case of the rat, for example, it has been found convenient to use such a response as depressing a horizontal bar. In birds—for example, the pigeon—a convenient response is pecking a key through a small hole in the wall. Each of these responses is easily specified and can be readily repeated. The pigeon may peck the key, for example, as rapidly as fifteen times per second.

To record the frequency of such a response we could, of course, use the standard polygraph, but another sort of curve has proved to be much more convenient. A pen is arranged to move one step across a strip of paper each time the organism responds. The result is a steplike diagonal line. Frequency is thus converted into the slope of the recorded line. Coordinates are chosen which convert the commonest frequencies into convenient slopes. If the organism is responding rapidly, the line is fairly steep. If it responds slowly, the slope is low. If it does not respond at all, the pen draws a horizontal line. With a little practice it is easy to estimate frequencies from the slopes of such graphs and to follow changes in frequency with fair accuracy. In Fig. 1 some actual records show the

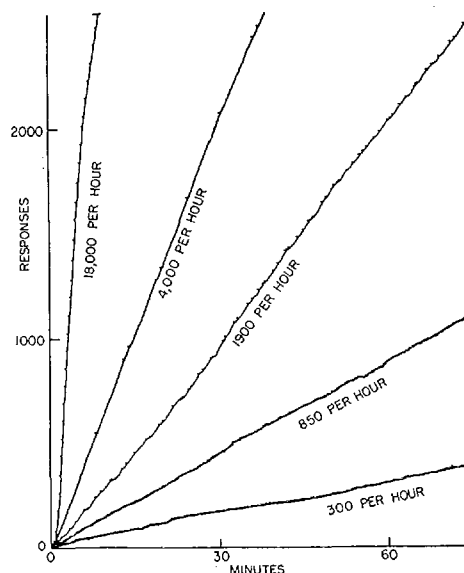


FIG. 1. Cumulative curves made by pigeons under various schedules of reinforcement showing relative uniform performance over a wide range of rates of responding.

range of frequencies encountered in the pigeon. The separate steps of the pen cannot be seen on this scale. One record shows a sustained rate of 18,000 responses per hour—five responses per second. Another record, by way of comparison, shows only 300 responses per hour—one response every twelve seconds—yielding a very low slope.

SCHEDULES OF REWARD

Frequency of response, so recorded, is a useful and significant datum in the experimental analysis of behavior. It is a sensitive "dependent variable" which has been found to be a function of many subtle experimental conditions. The degree of sensitivity is well illustrated by some results of a current research project² under the directorship of Dr. Charles Ferster and the author. This work falls within the traditional field of learning, a subject which demonstrates especially well the importance of frequency as a datum. Traditional experiments in learning have usually been concerned with changes in the character of behavior. The organism learns *how* to do something; it acquires new behavior. But the conditions which produce this kind of learning continue to have an effect when

² This research, carried out under Contract N5ori-07631 between Harvard University and the Office of Naval Research, has been under the direction of the author. Dr. Charles B. Ferster has served as principal investigator.

the character or topography of behavior no longer changes appreciably. The *form* of the response remains unaltered, but its *frequency* is nevertheless still affected.

Consider, for example, what we call a reward or, to use a more technical term suggested by Pavlov, a reinforcement. A convenient reinforcement is giving food to a hungry organism. If we arrange our apparatus so that a small amount of food is presented immediately after a selected response is made, we observe an immediate increase in the frequency of that response. By reinforcing slight variations in the form of response, we may mold behavior almost as a sculptor molds a lump of clay. In our experiments with pigeons the response of pecking the key on the wall may be conditioned in two or three minutes by selecting behavior which progressively approaches the form of this response. This is the kind of change traditionally studied in the field of learning. But when such behavior has been acquired, further reinforcements are not without effect. They no longer change the form of the response, but they maintain it as part of the current repertoire of the organism. This is seen in the simple fact that, unless a response continues to be reinforced, it disappears in what we call extinction. But there are many subtle degrees of probability of action between an inevitable response and no response at all.

The experiments to be described here are part of an extensive exploration of the effect of reinforcements which are only intermittently presented. In daily life the connection between a response and its consequences is usually not invariable, for it may depend upon events which are not fixed. We do not always win at cards or dice because the contingencies are so remotely determined that we call them "chance." We do not inevitably find good ice when we go skating—for very obvious reasons. Contingencies which require the participation of other people are especially likely to be uncertain. We do not always get a good meal in a restaurant because chefs are not always predictable. We do not always get an answer when we telephone a friend because the friend is not always at home. We do not always get a fountain pen by reaching into our pocket because this result depends upon our having put it there.

In analyzing the effect of intermittent reinforcement we have to distinguish between many different ways in which reinforcements may be scheduled.

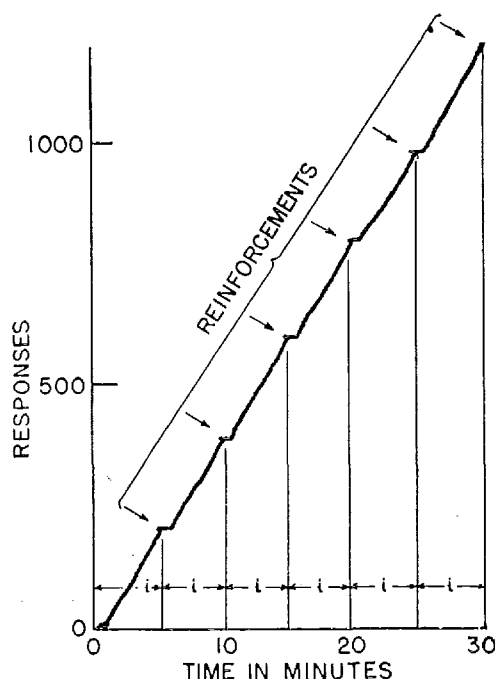


FIG. 2. Fixed-interval reinforcement. The interval (i) is 5 min.

In some of these a system outside the organism, such as a clock, arranges a connection between the movement of the key and the presentation of food. For example, a response to the key may be reinforced once every five minutes while all other responses are allowed to go unreinforced. In other schedules the reinforcements may be arranged by the organism itself—for example, we may reinforce every fiftieth response. These cases appear to be similar in the sense that we reinforce intermittently in both, but subtle differences in the schedules lead to very different results, many of which are of great practical significance.

We might study the subject by specifying all possible schedules or programs of reinforcement and by determining the typical performance generated by each. In one sense this would give us a complete picture. But a thorough analysis must go further. *Why* does a given schedule yield a given performance? We cannot suppose that it is simply because organisms are fond of mathematics. We need to examine the way in which a particular schedule actually affects the organism. The only point of contact between the scheduling mechanism and the organism occurs at the moment of reinforcement. Dr. Ferster and I have therefore attempted to account for the performance character-

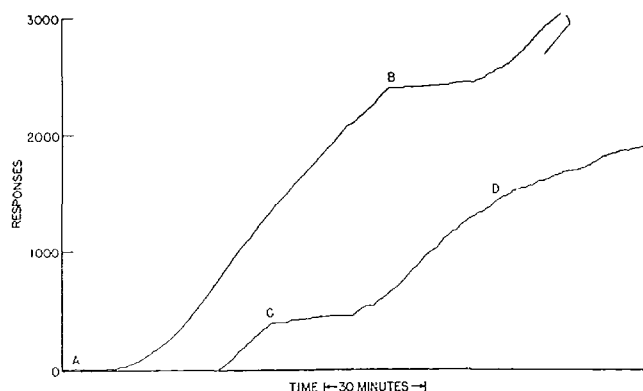


FIG. 3. Extinction after fixed-interval reinforcement. The record has been broken into two segments to avoid undue reduction.

istic of a given schedule in terms of the conditions which prevail at the moment of reinforcement. The experimental problem is to separate these conditions so that their contributions may be evaluated.

We may represent a schedule in which reinforcements are arranged by a clock by drawing vertical lines on our cumulative graph. In Fig. 2 the lines are five minutes apart. A response is reinforced as soon as the pen reaches the first line, regardless of how many responses have been made. Another response is reinforced when the pen reaches the second line, and so on. In other words, we simply reinforce responses at intervals of approximately five minutes. Call this "fixed-interval reinforcement." The organism quickly adjusts with a fairly constant rate of responding, which produces a straight line with our method of recording. The rate—the slope of the line—is a function of several things. It varies with difficulty of execution: the more difficult the response, the lower the slope. It varies with degree of food deprivation: the hungrier the organism, the higher the slope. And so on. It will be seen, moreover, that such a record is not quite straight. After each reinforcement the pigeon pauses briefly—in this case for 30 or 40 seconds. This is due to the fact that under a fixed-interval schedule no response is ever reinforced just after reinforcement. The organism is able to form a discrimination based upon the stimuli generated in the act of eating food. So long as this stimulation is effective, the rate is low. Thereafter the organism responds at essentially a constant rate. It would appear that stimuli due to the mere passage of time are not significantly different to the organism during the remaining part of the interval. The organism cannot, so to speak, tell the difference be-

tween, say, three and four minutes after reinforcement under these circumstances. At longer fixed intervals—of, say, 15 minutes—each segment of such a record is a smooth, positively accelerated curve.

A pigeon will continue indefinitely to respond when reinforcements are spaced as much as 45 minutes apart. Food is then received too slowly to maintain body-weight, so that extra feeding is necessary between experimental periods. The behavior after each reinforcement shows a much slower acceleration from a low to a high rate. In extinction, the effect of self-generated stimuli is seen. Figure 3 is an example, broken into two segments to show details more clearly. The pigeon begins as usual at a low rate of responding at A. It has never been reinforced at the start of the experiment or immediately after another reinforcement. A higher rate develops smoothly during the first 20 or 30 minutes. This part of the curve is a fair sample of the behavior after each reinforcement on a 45-minute schedule. Eventually a rate is reached at which reinforcements have been most often received. (This is by no means the highest rate of which the pigeon is capable.) Because this is an optimal condition, the rate prevails for some time. When the pigeon pauses for a few moments (at B), it creates a condition which is not optimal for reinforcement. Responding is therefore not resumed for some time. Eventually another slow acceleration leads to the same high rate. When this is again broken (at C), another period of slow responding intervenes, followed by another acceleration. Eventually the rate falls off in extinction. Although such a curve is complex, it is not disorderly. It is by no means random responding. Since no

external condition changes during the experimental period, the change in rate must be due to conditions altered by the bird's own behavior.

We can test the importance of the passage of time in accounting for behavior of this sort by giving the pigeon an external "clock." One such clock consists of a spot of light projected upon the key which the pigeon pecks. The spot marks time by changing size. At first it is only $\frac{1}{8}$ th of an inch in length. It grows to $\frac{3}{4}$ th of an inch at a given rate. The response to the key is reinforced when the spot is largest. When the pigeon returns to the key after reinforcement, the spot has again become small. Here is an external stimulus, then, roughly proportional to the time which has passed since the last reinforcement. Can it be used by the pigeon as a discriminative stimulus?

To avoid a disturbing complication we must get the spot of light into the experiment before it functions as a clock. Suppose we begin by holding the spot still at its largest size, and build up the usual fixed-interval performance. In Fig. 4 the upper

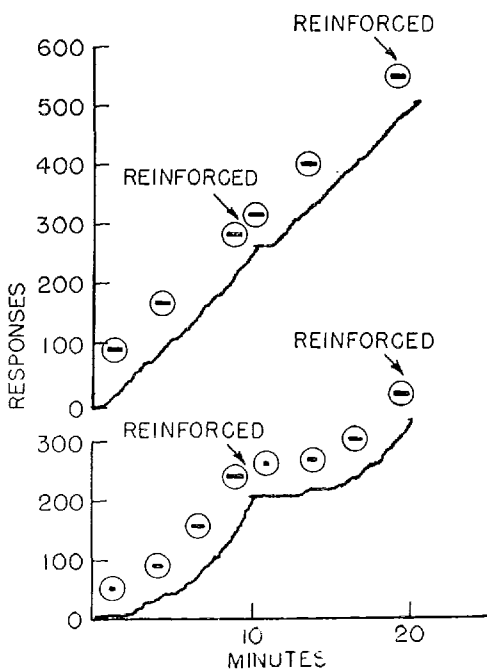


FIG. 4. First effect of allowing a spot of light to change size as a function of time. Upper curve: typical performance under fixed-interval reinforcement with the spot of light at "large" as shown in the circles. Lower curve: first effect of changing the spot to "small" immediately after reinforcement and allowing it to grow linearly during the following interval of 10 min. Sample sizes of the spot are shown in the circles.

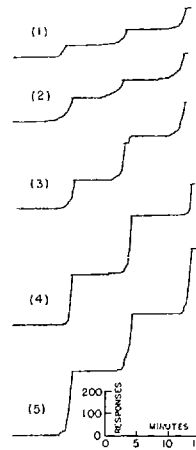


FIG. 5. Progressive change in the pigeon's response to an external clock. The series (1) through (5) illustrates the increasing effectiveness of the spot of light as a discriminative stimulus.

curve shows a standard sample. The spot was set at "large" and the record is typical of reinforcement at intervals of ten minutes. We now—for the first time—change the size of the spot, letting it begin at "small" to grow progressively larger during the interval. The spots in the circles above the lower record give sample readings of the clock at various positions. We observe that the pigeon is sensitively controlled by the size. When the spot is small it is most unlike its accustomed size, and the rate is almost zero. As the spot grows, the similarity increases and the rate rises. As the spot reaches its final standard size, the rate has reached or exceeded the value at which responses have been reinforced. Such a curve is not the effect of the passage of time; it is the effect of stimulus generalization from large spots to smaller ones.

Eventually, however, the correlation between the size of the spot and the passage of time is felt. The pigeon begins, so to speak, to "tell time." In Fig. 5 a series of records show the progress of a pigeon in learning to use the clock projected upon the key. Groups of three intervals each have been selected from a single experimental record. In Record 1 the curvature is already somewhat sharper than in the preceding figure. As the pigeon is repeatedly exposed to the changing spot and is reinforced only when the spot is large, these gradients become sharper still. By the time Record 5 is reached, the pigeon is not responding for approximately the first seven or eight minutes out of each ten. By that time the spot has reached a size very close to opti-

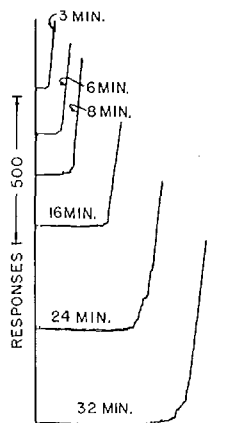


FIG. 6. Typical performances with the clock moving at different speeds. The clock completes the cycle from "small" to "large" in a given number of minutes as marked.

mal and responding then begins and soon reaches a very high rate.

Eventually the pigeon characteristically waits fully eight out of the ten minutes and responds at a rate of four or five responses per second during the remaining part of the interval. It has formed a very precise size discrimination. This would be the result without an added clock if the pigeon had what we call a precise "sense of time," but it is obvious that the unamplified passage of time is very insignificant for the pigeon compared with a physical clock of this sort.

The extent of the control exercised by the size of the spot is beautifully illustrated if we withhold further reinforcement while allowing the clock to run, repeating cycle after cycle of the growth of the spot from small to large during extinction. The pigeon continues not to respond during all sizes of the spot except those close to the value which has previously obtained at reinforcement. As repeated responses go unreinforced, however, the amount of responding to the high value progressively decreases. The extent of the control exercised by the spot can be shown in many other ways. We discovered one of these by accident. Our experiments are automatic, and our apparatus is used 24 hours of the day. When we reached the laboratory one morning, we found that a pigeon had not responded all night long. Investigation showed that through an oversight the clock had not been started. The spot had remained at its smallest size for 15 hours. During this time the pigeon had not made a single response to the key.

At the other extreme, we can show the enormous

stimulating power of the clock stopped at its optimal size. In a typical experiment the pigeon responded nearly 2,000 times during a single 10-minute interval with the clock set at "large." This extraordinary stimulus control far exceeds that obtained through the discrete presentation of discriminative stimuli. A continuously varying stimulus may possibly form the basis for a more sensitive psychophysical technique.

When time has been, so to speak, externalized in this way, it may be manipulated. For example, our clock may be made to run fast or slow. In one experiment, various "speeds of time" were introduced at random in successive intervals. The clock might complete one cycle in, say, 6 minutes, at the end of which time a response would be reinforced; the next cycle might require 16 minutes; and so on. The extent of the control exercised over the bird's behavior is seen in Fig. 6, where typical performances for a range of clock speeds between one cycle in 3 minutes and one cycle in 32 minutes are shown. The rate of responding is roughly the same for a given size of spot regardless of speed of change. The curve at 32 minutes is obviously not approximately 10 times as high as that at 3 minutes, however, as it should be if the control by the spot were strictly equivalent in both cases.

It is also possible to run externalized time backward. Our first experiment of this sort was also an accident. The bird was being studied with a 3-minute clock and was responding as shown at the left in Fig. 7. The next day, through an oversight, the clock was run backward. The spot began large

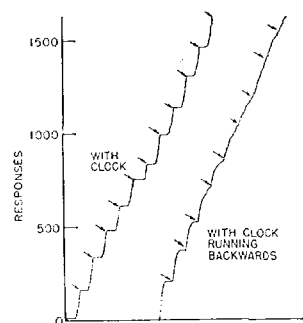


FIG. 7. The effect of the clock running backwards. Left curve: standard performance with the clock operating as in earlier graphs. Right curve: record obtained when the clock was accidentally reversed. The control exercised by the size of the spot completely masks any effect of the passage of time and inverts the standard curve. Successive reinforcements with the clock at "small" soon destroy this control.

and grew small. The first three segments of the second curve in Fig. 7 are essentially inversions of the segments of the other curve. Since the bird was now reinforced when the spot was small, however, a new pattern quickly arose. The curve becomes essentially linear and at a later stage the usual performance with a clock developed.

We may eliminate the effect of time by adopting a different schedule, in which reinforcement is still controlled by a clock, but the intervals are varied, roughly at random, within certain limits and with a given mean. In such a case the bird cannot predict, so to speak, when the next reinforcement is to be received. This is called variable-interval reinforcement. The effect is a uniform rate of responding with great stability, which may be maintained for many hours. During a single experimental period of fifteen hours a bird responded 30,000 times. Toward the end of the record there was one pause approximately one minute long but otherwise the bird did not pause longer than fifteen seconds at any

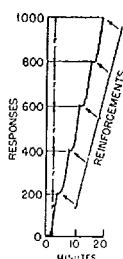


FIG. 8. Fixed-ratio reinforcement. The ratio (r) is 200 responses per reinforcement.

time during the fifteen hours. During this period the bird received less than its daily ration of food.

We turn now to an entirely different type of schedule. The moment at which a response is to be reinforced may be determined by the behavior of the organism itself. For example, we may reinforce every fifth response, every fiftieth response, or every two-hundredth response. We call this "fixed-ratio reinforcement." In industry, it is called piece-work pay. The pigeon's behavior under such a schedule is not too difficult to interpret. Figure 8 shows a short segment of a characteristic performance. A response is reinforced every time the pigeon completes a group of 200 responses. Just as we represented a fixed-interval reinforcement by drawing vertical lines on our cumulative graph, so here we may represent fixed-ratio reinforcement with a series of horizontal lines. When-

ever the curve reaches one of these lines a response is reinforced, no matter how much time has elapsed.

The results depend upon the size of the ratio. For ratios which may be easily maintained—for example, a ratio of 100:1 for the pigeon—the curves are essentially straight lines of high slope. Immediately after each reinforcement, however, a low rate of responding prevails which may be extended into long delays when the ratios are high. The transition from a low to a high rate between reinforcements is sometimes of such a nature that the curve shows a smooth gradient as in Fig. 8. Otherwise the change from no responding to rapid responding is usually abrupt. The high rate which prevails when the organism is responding appears to be due to another source of stimulation available under fixed-ratio reinforcement. In addition to a clock the pigeon presumably has a "counter" which tells it how many responses it has made since the previous reinforcement.

An increase in its counter reading may be immediately reinforcing to the pigeon. One way to test this is to add an external counter comparable to the external clock. The spot of light on the key is made to grow, not with the passage of time, but with the accumulation of responses. If the pigeon does not respond, the spot remains stationary. With each response it grows by a small amount. The effect of this externalized counter is dramatic. In one experiment the pigeon was being reinforced approximately every 70 responses. It was proceeding at an over-all speed of about 6,000 responses per hour. As soon as a spot of light was added to the key, in such a way that it grew from "small" to "large" as the effect of 70 responses, the rate went up almost immediately to 20,000 responses per hour. Pauses after reinforcement disappeared. Obviously the pigeon's own "counter" is much less effective than the spot of light. It is possible to carry a pigeon to a high ratio without introducing appreciable pauses after reinforcement, but this process is slow and must be carried out with great care, presumably because the pigeon must be made sensitive to changes in its own counter.

We can prove that the pigeon is, so to speak, counting its responses by setting up a two-valued schedule of reinforcement. We reinforce the fiftieth response after the preceding reinforcement or the two hundred and fiftieth, and we arrange our program in such a way that there is no indication in advance of which ratio is to prevail. In such a

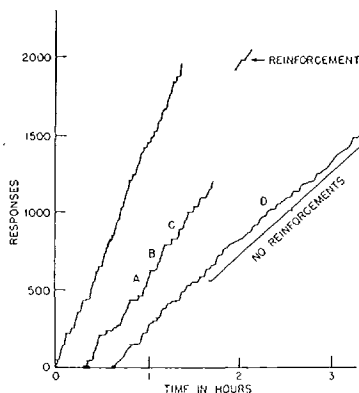


FIG. 9. Two-valued reinforcement. Ratios of 50:1 and 250:1 in random order.

case, the pigeon develops a steplike curve appropriate to a ratio of 50:1. But it shows this, of course, even when the ratio is actually 250:1. In Fig. 9, for example, the segments at A, B, and C show either three or four waves which are the gradients prevailing under a reinforcement of 50:1. The pigeon begins as if the ratio were to be 50:1, but after 60 or 70 responses have been completed there is a marked decrease in rate which can be explained only by assuming that the bird "knows the score." A short period of slow responding follows. This gives way to a second gradient, again roughly of the order prevailing under 50:1 reinforcement. This may be followed by a third or even fourth gradient before reinforcement is received at the two-hundred-and-fiftieth response. If, as at D, we simply withhold all reinforcements, an extinction curve emerges in the form of a series of waves, averaging approximately 50 responses each. This cannot be due to the mere passage of time, since

time does not show a wavelike character. It cannot be due to a discrimination based upon the rate of responding, because this should lead to long segments at a high rate as in both fixed-interval and fixed-ratio reinforcement. We have, then, to take into account a third source of automatic stimulation at the moment of reinforcement provided by a "counter."

We can eliminate the "counter" by randomizing a schedule of many different ratios. In a typical experiment with what we may call "variable-ratio reinforcement," a response was reinforced on the average every one hundred and ten responses, but in actual practice the very next response or a response as many as 500 responses later might be reinforced. The schedule produced a rate of responding of approximately 12,000 responses per hour, which was sustained for long periods of time without any of the oscillations in rate characteristic of fixed-ratio reinforcement. This variable-ratio schedule is familiar to everyone, because it is the fundamental feature of all gambling devices. The pigeon making 12,000 responses per hour is not far removed from the pathological gambler. Variable-ratio reinforcement engages and holds the behavior of the organism with particular power. The magnitude of its control is seen when we extinguish the response. Figure 10 is an extinction curve obtained after the variable-ratio reinforcement just described. The curve has been broken into consecutive segments in order to avoid undue reduction. It begins with a long run of approximately 7,500 responses during which there is no appreciable retardation. The remainder of the curve is also illuminating. After short periods of slow re-

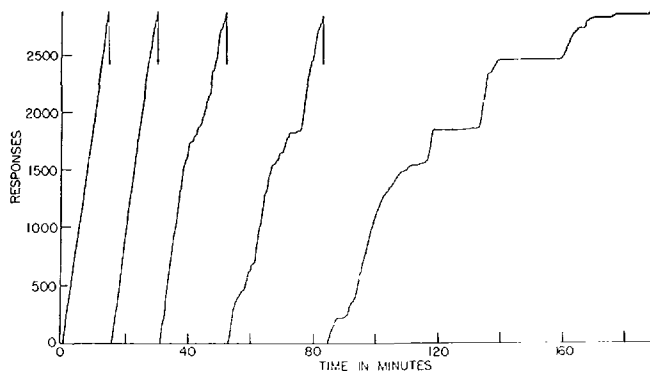


FIG. 10. Extinction after variable-ratio reinforcement. The mean ratio was 110 responses per reinforcement. The record has been broken into segments.

sponding the pigeon returns again and again to the original rate which, as the prevailing condition at previous reinforcements, tends to perpetuate itself.

FREQUENCY OF RESPONDING AS AN EXPERIMENTAL DATUM

Intermittent reinforcement is widely used in the control of human behavior. Many different kinds of wage systems illustrate it, and the schedules characteristic of gambling devices play a powerful role. Almost all the complex behavior which we used to speak of as representing the higher mental processes arises from differential reinforcement which is necessarily intermittent, and we cannot evaluate such processes until the contributions of the schedules themselves have been discovered. This material is presented here, however, merely to exemplify the kind of result which follows when one takes probability—or, more immediately, frequency—of response as a subject matter. The following points seem to be justified.

1. Frequency of response is an *extremely orderly datum*. The curves which represent its relations to many types of independent variables are encouragingly simple and smooth.

2. The results are *easily reproduced*. It is seldom necessary to resort to groups of subjects at this stage. The method permits a direct view of behavioral processes which have hitherto been only inferred. We often have as little use for statistical control as in the simple observation of objects in the world about us. If the essential features of a given curve are not readily duplicated in a later experiment—in either the same or another organism—we take this, not as a cue to resort to averages, but as a warning that some relevant condition has still to be discovered and controlled. In other words, the uniformity of our results encourages us to turn, not to sampling procedures, but to more rigorous experimental control.

3. As a result of (2) the concepts and laws which emerge from this sort of study have an *immediate reference* to the behavior of the individual which is lacking in concepts or laws which are the products of statistical operations. When we extend an experimental analysis to human affairs in general, it is a great advantage to have a conceptual system which refers to the single individual, preferably without comparison with a group. A more direct application to the prediction and control of the

individual is thus achieved. The study of frequency of response appears to lead directly to such a system.

4. Frequency of response provides a *continuous* account of many basic processes. We can follow a curve of extinction, for example, for many hours, and the condition of the response at every moment is apparent in our records. This is in marked contrast to methods and techniques which merely sample a learning process from time to time, where the continuity of the process must be inferred. The samples are often so widely spaced that the kinds of details we see in these records are missed.

5. We must not forget the considerable advantage of a datum which lends itself to *automatic experimentation*. Many processes in behavior cover long periods of time. The records we obtain from an individual organism may cover hundreds of hours and report millions of responses. We characteristically use experimental periods of eight, ten, or even fifteen hours. Personal observation of such material is unthinkable.

6. Perhaps most important of all, frequency of response is a valuable datum just because it provides a *substantial basis for the concept of probability of action*—a concept toward which a science of behavior seems to have been groping for many decades. Here is a perfectly good physical referent for such a concept. It is true that the momentary condition of the organism as the tangent of a curve is still an abstraction—the very abstraction which became important in the physical sciences with Newton and Leibnitz. But we are now able to deal with this in a rigorous fashion. The superfluous trappings to be found in traditional definitions of terms like habit, attitude, wish, and so on, may be avoided.

The points illustrated here in a small branch of the field of learning apply equally well to other fields of behavior. Frequency of response has already proved useful in studying the shaping of new responses and the interaction between responses of different topography. It permits us to answer such a question as: Does the emission of Response A alter the probability of Response B, which resembles A in certain ways? It has proved to be a useful datum in studying the effect of discriminative stimuli. If we establish a given probability of response under Stimulus A, we can discover the probability that the response will be made under Stimu-

lus B, which resembles A. The question "Is red as different from orange as green is from blue?" is quite meaningful in such terms. Pattern discrimination and the formation of concepts have been studied with the same method.

Frequency of response is also a useful datum when two responses are being considered at the same time. We can investigate the behavior of making a choice and follow the development of a preference for one of two or more stimuli. The datum has proved to be especially useful in studying complex behavior in which two or more responses are related to two or more stimuli—for example, in matching color from sample or in selecting the opposite of a sample. Outside the field of learning considerable work has been done in the fields of motivation (where frequency of response varies with degree of deprivation), of emotion (where, for example, rate of responding serves as a useful baseline in observing what we may call "anxiety"), of the effects of drugs (evaluated, for example, against the stable baseline obtained under variable-interval reinforcement), and so on. One of the most promising achievements has been an analysis of punishment which confirms much of the Freudian material on repression and reveals many defects in the use of punishment as a technique of control.

The extension of such results to the world at large frequently meets certain objections. In the laboratory we choose an arbitrary response and hold the environment as constant as possible. Can our results apply to behavior of much greater variety emitted under conditions which are constantly changing? If a certain experimental design is necessary to observe frequency, can we apply the results to a situation where frequency cannot be determined? The answer here is the answer which must be given by any experimental science. Laboratory experimentation is designed to make a process as obvious as possible, to separate one process from another, and to obtain quantitative measures. These are the very heart of experimental science. The history of science shows that such results can be effectively extended to the world at large. We determine the shape of the cooling curve only with the aid of the physical laboratory, but we have little doubt that the same process is going on as our breakfast coffee grows cold. We have no evidence for this, however, and probably could not

prove it under genuine breakfast-table conditions. What we transfer from the laboratory to the casual world in which satisfactory quantification is impossible is the knowledge that certain basic processes exist, that they are lawful, and that they probably account for the unpleasantly chaotic facts with which we are faced. The gain in practical effectiveness which is derived from such transferred knowledge may be, as the physical sciences have shown, enormous.

Another common objection is that if we identify probability of response with frequency of occurrence, we cannot legitimately apply the notion to an event which is never repeated. A man may marry only once. He may engage in a business deal only once. He may commit suicide only once. Is behavior of this sort beyond the scope of such an analysis? The answer concerns the definition of the unit to be predicted. Complex activities are not always "responses" in the sense of repeated or repeatable events. They are composed of smaller units, however, which are repeatable and capable of being studied in terms of frequency. The problem is again not peculiar to the field of behavior. Was it possible to assign a given probability to the explosion of the first atomic bomb? The probabilities of many of the component events were soundly based upon data in the form of frequencies. But the explosion of the bomb as a whole was a unique event in the history of the world. Though the probability of its occurrence could not be stated in terms of the frequency of a unit at that level, it could still be evaluated. The problem of predicting that a man will commit suicide is of the same nature.

SUMMARY

The basic datum in the analysis of behavior has the status of a probability. The actual observed dependent variable is frequency of response. In an experimental situation in which frequency may be studied, important processes in behavior are revealed in a continuous, orderly, and reproducible fashion. Concepts and laws derived from such data are immediately applicable to the behavior of the individual, and they should permit us to move on to the interpretation of behavior in the world at large with the greatest possible speed.

Manuscript received May 12, 1952